International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

Optimization of Material Removal Rate and Surface Roughness in Turning of Aluminum, Copper and Gunmetal Materials using RSM

T. K Durga Bhavani
Assistant Professor
Mechanical Engineering Department
S.R.K.R Engineering College
Bhimavaram, India

G. S .V Seshu Kumar
Assistant Professor
Mechanical Engineering Department
S.R.K.R Engineering College
Bhimavaram, India

Prof. K Satyanarayana
Professor
Mechanical Engineering Department
S.R.K.R Engineering College
Bhimavaram, India

I. Ajit Kumar
Assistant Professor
Mechanical Engineering Department
S.R.K.R Engineering College
Bhimavaram, India

***Abstract*— *Surface roughness and material removal rate play a* major role in the process of machining. The surface roughness plays vital role in appearance, touch and feel of the component while material removal rate influences the surface finish as well as cost and economics of machining. Therefore study of surface roughness and material removal rate has acquired major attention. The present study aims to investigate the effect of spindle speed, feed rate and depth of cut on material removal rate (MRR) and Surface roughness, in turning of aluminium, copper and gunmetal using Tungsten carbide tip on CNC Lathe machine.**

The effect of cutting parameter on MRR and surface roughness were studied and analyzed. Experiments were conducted based on the Taguchi design of experiments (DOE) with orthogonal L9 array, and then followed by optimization of the results using Analysis of Variance (ANOVA) to find the optimum MRR and surface roughness. The optimum values were obtained when setting the cutting parameter at high values. RSM technique was used to validate the results with experiments. The results obtained for MRR and surface roughness using RSM technique were in a good agreement with the experiments.

Keywords*— *Material Removal Rate, Surface Roughness, Process Parameters, Taguchi Design, ANOVA

I. INTRODUCTION

Turning is one of the important metal cutting processes used extensively in the finishing operations. Metal removal rate and surface finish are the important output responses in the production with respect to quantity and quality. Based on the literature it was identified that turning parameters like spindle speed, feed rate, depth of cut etc. influence the metal removal rate and surface roughness.

In general, there are three computational methods i.e. Neural network modeling and Adaptive-neuro fuzzy inference system (ANFIS) and Regression analysis was used to predict metal removal rate of work piece for variety of cutting conditions in turning process. Total 9 experiments were conducted on CNC lathe machine by taking spindle speed, depth of cut and feed rate as process parameters. The output response considered in the present work was metal removal rate and surface roughness.

Analysis of material removal rate involves large number of parameters including cutting parameters, tool geometry, work material, chatter and cutting fluids. Establishment of optimum machining parameters keeping in view reduction in machining time, productivity, quality plays a vital role in competitive market and is subject of many studies. Increase in productivity results in reduction in machining time which may result in quality loss. On the contrary, an improvement in quality results in increasing machining time the by reducing productivity.

So far several investigations have been carried out to predict material removal rate in turning operations considering the spindle speeds, feed rate and depth of cut on aluminium, copper and gunmetal. It would be difficult to correlate material removal rate with any one parameter alone. So, allowable spindle speed, feed rate, depth of cut is included in model.

A. Turning Operation-Parameters

In turning, the speed and motion of the work piece is specified through several parameters. The parameters, cutting speed, feed and depth of cut are selected for each operation based upon the work piece material, tool material, tool size etc.

B. Material Removal Rate

Understanding of material removal concept (MRR) in metal cutting is very important in designing process and cutting tool selection to ensure the quality of the product. The material removal rate (MRR) in turning operations is the volume of material/metal that is removed per unit time in mm3/sec. For each revolution of the work piece, a ring shaped layer of material is removed.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

Material Removal Rate (MRR) for Turning:
MRR= Volume removed/cutting time
Where
Volume removed = (initial mass-final mass)/density of material
Machining time= L/(F*N)
L= machining length (mm), F= feed rate (mm/rev), N= speed in rpm

C. Optimization
Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface (see surface metrology). However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion.

Although a high roughness value is often undesirable, it can be difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

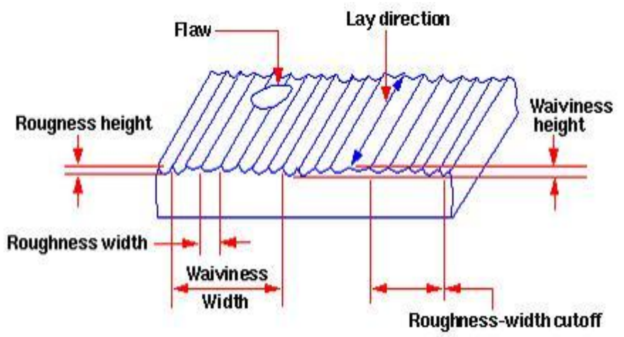


Figure 1.Surface Characteristics.

II. PROBLEM DEFINITION

Turning is one of the important metal cutting processes used extensively in the finishing operations. Metal removal rate and surface finish are the important output responses in the production with respect to quantity and quality. Based on the literature it was identified that turning parameters like spindle speed, feed rate, depth of cut etc. influence the metal removal rate and surface roughness.

In general, there are three computational methods i.e. Neural network modeling and Adaptive-neuro fuzzy inference system (ANFIS) and Regression analysis was used to predict metal removal rate of work piece for variety of cutting conditions in turning process. Total 9 experiments were conducted on CNC lathe machine by taking spindle speed, depth of cut and feed rate as process parameters. The output response considered in the present work was metal removal rate and surface roughness.

Analysis of material removal rate involves large number of parameters including cutting parameters, tool geometry, work material, chatter and cutting fluids. Establishment of optimum machining parameters keeping in view reduction in machining time, productivity, quality plays a vital role in competitive market and is subject of many studies. Increase in productivity results in reduction in machining time which may result in quality loss. On the contrary, an improvement in quality results in increasing machining time the by reducing productivity.

So far several investigations have been carried out to predict material removal rate in turning operations considering the spindle speeds, feed rate and depth of cut on aluminium, copper and gunmetal. It would be difficult to correlate material removal rate with any one parameter alone. So, allowable spindle speed, feed rate, depth of cut is included in model.

III. DESIGN OF EXPERIMENTS

The design of experiments includes the process parameters for turning operation. The process parameters considered are speed, feed, and depth of cut (DoC). The individual experiments are conducted on the test samples and all data is collected CNC machine is utilized to perform the experimentation on the samples for turning operation. The set up also includes the surface roughness tester called stylus profiolometer.

A. Surface Roughness Tester and its Measurement
After measuring the Material Removal Rate (MRR) the Surface roughness measurements were conducted with a stylus profilometer to measure the work piece in the Z-axis (lay) direction. So that Surface Roughness values at same input parameters is obtained. The device was a Pocket Surf stylus profilometer, set up to measure Ra in µm with a travel length of 8mm. The above described experimental setup was used to turn the sample work pieces and collect data for the purposes of training the system.

B. Materials Used
Three materials viz., Aluminium, Copper and Gunmetal are utilized for the purpose of experimentation as samples. Gunmetal used in this experiment is also known as red brass. It is an alloy composed of copper (85%), tin (10%), zinc (5%) and lead (5%).

The experimental values obtained from machining are used for training and testing and then the prediction and optimization is done.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

TABLE 1: PROPERTIES OF MATERIALS

S.No	Density (kg/m^3)	Young's Modulus (GPa)	Shear Modulus (GPa)	Bulk Modulus (GPa)	Poisons Ratio
Aluminium	2700	70	26	76	0.35
Copper	8900	120	48	140	0.34
Gunmetal	8700	115	40	125	0.33

C. Cutting Tool Used

The tool used is a Tungsten Carbide tipped tool which is a chemical compound containing equal parts of tungsten and carbon. In its basic form it is a very fine gray powder. But it can be pressed and formed into shapes for use in industrial machinery, tools and abrasives. Tungsten Carbide is extremely hard with melting point of 2,870 ^{o}C.

The cutting parameters used for the experimentation of turning operation are tabulated as follows

TABLE 2: PROCESS PARAMETERS

S.No	Speed (rpm)	Feed (revol/min)	DoC (mm)
1	600	0.5	0.15
2	600	1.0	0.20
3	600	1.5	0.25
4	800	0.5	0.15
5	800	1.0	0.20
6	800	1.5	0.25
7	1000	0.5	0.15
8	1000	1.0	0.20
9	1000	1.5	0.25

IV. RESULTS AND DISCUSSION

A. For the material removal rate

The dominant factors among the speed, feed and depth of cut are represented in the following plots. The dominant factor influencing the machining of aluminium is feed and speed. The dominant factors for Copper are feed and speed. The dominant factors for gunmetal are feed and speed, while the other parameters have negligible effect on the material removal rate.

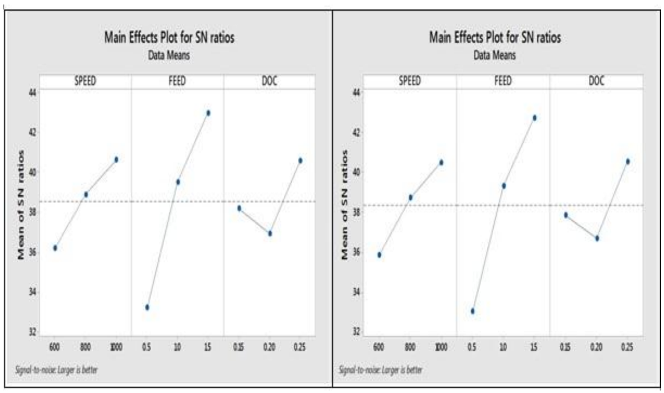


Figure 2 Cutting Parameters Vs S/N Ratios for Aluminium and Copper

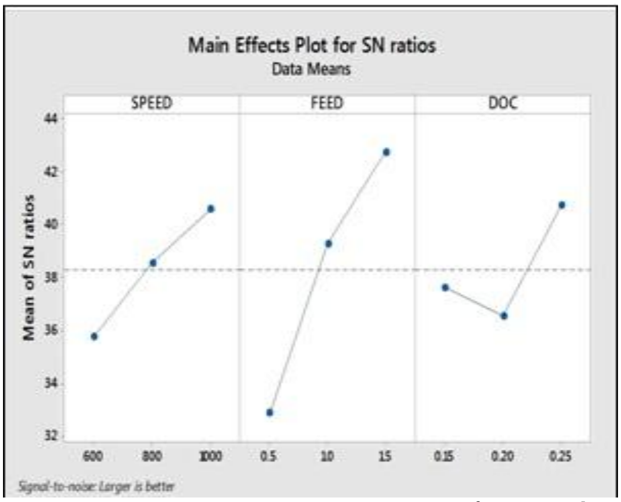


Figure 3 Cutting Parameters Vs S/N Ratios for Gunmetal

TABLE 3 : ANOVA ANALYSIS OF S/N RATIO FOR MRR

Aluminium					
Source	DOF	Seq SS	Adj MS	F	%
Speed	1	1951.2	1951.2	11.95	11.18
Feed	1	13075.5	13075.5	80.08	74.96
DoC	1	1599.0	1599.0	9.79	9.16
Error	5	816.4	163.2		
Total	8	17442.1			

TABLE 4 : ANOVA ANALYSIS OF S/N RATIO FOR MRR

Copper					
Source	DOF	Seq SS	Adj MS	F	%
Speed	1	2043.8	2043.8	10.48	11.82
Feed	1	12364.3	12364.3	63.45	71.52
DoC	1	1903.7	1903.7	9.77	11.01
Error	5	974.2	194.84		
Total	8	17286.1			

TABLE 5 : ANOVA ANALYSIS OF S/N RATIO FOR MRR FOR GUNMETAL

Source	DOF	Seq SS	Adj MS	F	%
Speed	1	1756.5	1756.5	9.753	11.06
Feed	1	12841.5	12841.5	71.32	73.57
DoC	1	1954.7	1954.7	10.84	10.19
Error	5	900.4	180.08		
Total	8	17453.1			

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

GRAPHICAL COMPARISON OF MATERIAL REMOVAL RATE OF ALUMINIUM, COPPER AND GUNMETAL:

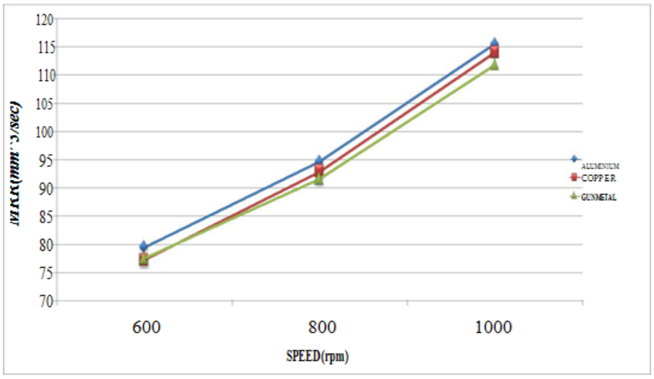


Figure 4 Speed Vs MRR

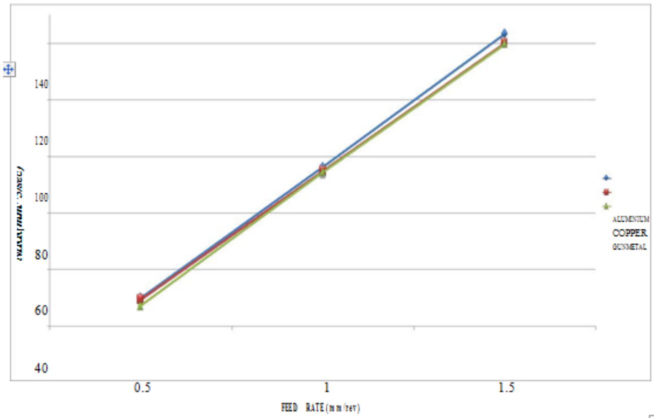


Figure 5 Feed Vs MRR

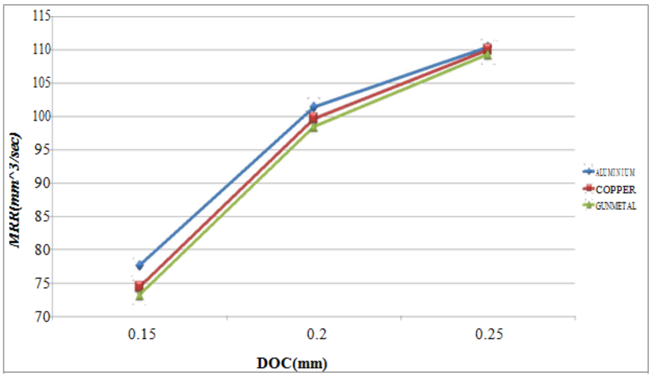
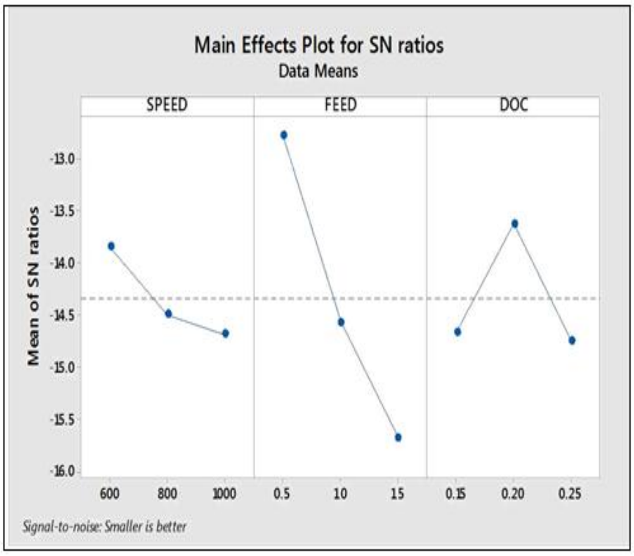


Figure 6: Depth of cut Vs MRR

From the above graphs it is inferred that, as speed increases Material Removal Rate increases for Aluminium, Copper and Gunmetal. Material removal rate of Aluminium is more than copper, gunmetal. On X-axis speed values and on Y-axis material removal rate are taken. Similarly as Feed rate increases Material Removal Rate increases for Aluminium, Copper and Gunmetal. Material removal rate of Aluminium is more than copper, gunmetal. On X-axis Feed rate values and on Y-axis material removal rate are taken. As Depth of cut increases Material Removal Rate increases for Aluminium, Copper and Gunmetal. Material removal rate of Aluminium is more than copper, gunmetal. On X-axis Depth of cut values and on Y-axis material removal rate are taken.

B. For the surface Roughness



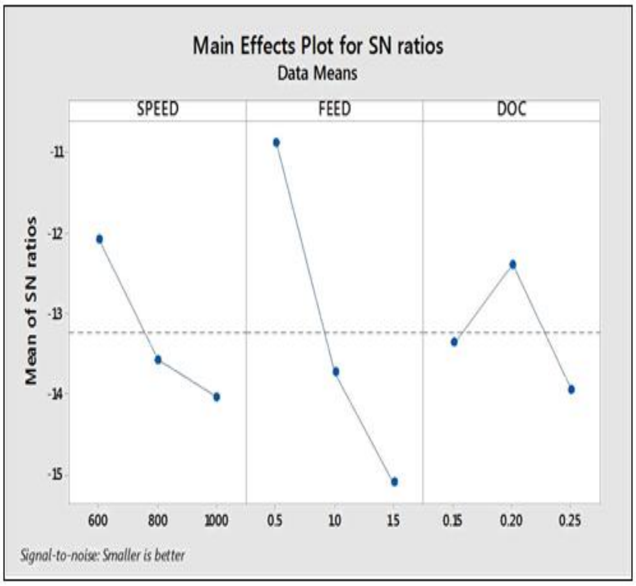


Figure 7: Cutting Parameters Vs S/N Ratios for Aluminium and copper

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

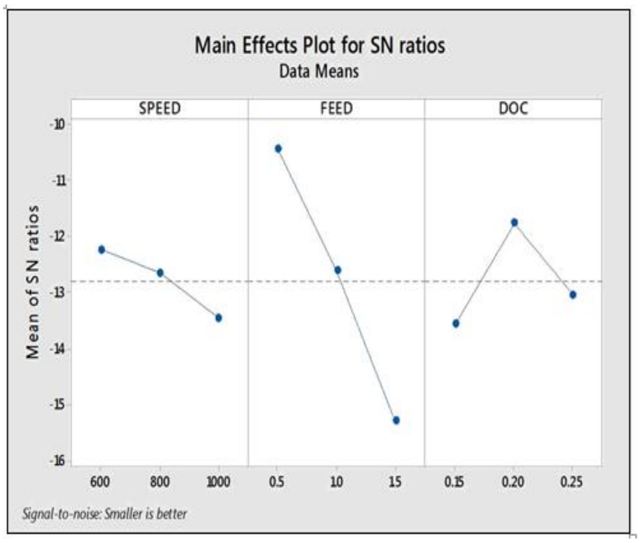


Figure 8.Cutting Parameters Vs S/N Ratios for Gun Metal

The dominant factors among the speed, feed and depth of cut are represented in the above plots indicate, the main effects of cutting parameters on Surface Roughness of Aluminum, Copper and Gunmetal. From the plots it is inferred that, for Aluminum the feed rate is most significant parameters than cutting speed in controlling the Surface Roughness. As the feed rate increases, Surface Roughness also increases. Similarly for Copper, the feed rate is most significant parameters than cutting speed in controlling the Surface Roughness. As the feed rate increases, Surface Roughness also increases. In the same way for Gunmetal also, the feed rate is most significant parameters than cutting speed in controlling the Surface Roughness. As the feed rate increases, Surface Roughness also increases. This is mainly due to more volume of chips generated during machining.

TABLE 6 : ANOVA ANALYSIS OF S/N RATIO FOR SURFACE ROUGHNESS

Aluminium					
Source	DOF	Seq SS	Adj MS	F	%
Speed	1	0.7352	0.7352	15.43	10.95
Feed	1	4.7572	4.7572	70.64	70.86
DoC	1	0.5232	0.5232	4.41	7.77
Error	5	1.5209	0.3042		
Total	8	6.7134			

TABLE 7 : ANOVA ANALYSIS OF S/N RATIO FOR SURFACE ROUGHNESS

Copper					
Source	DOF	Seq SS	Adj MS	F	%
Speed	1	1.3095	1.3094	14.01	14.44
Feed	1	7.2745	7.2744	77.85	80.23
DoC	1	0.3368	0.3368	3.60	3.71
Error	5	0.4672	0.0934		
Total	8	9.0688			

TABLE 8 : ANOVA ANALYSIS OF S/N RATIO FOR SURFACE ROUGHNESS FOR GUNMETAL

Source	DOF	Seq SS	Adj MS	F	%
Speed	1	1..2221	1.2221	11.30	12.26
Feed	1	8.9457	8.9457	75.50	89.75
DoC	1	0.5130	0.5130	3.55	5.14
Error	5	0.2310	0.04621		
Total	8	9.9665			

GRAPHICAL COMPARISON OF SURFACE ROUGHNESS OF ALUMINUM, COPPER AND GUNMETAL:

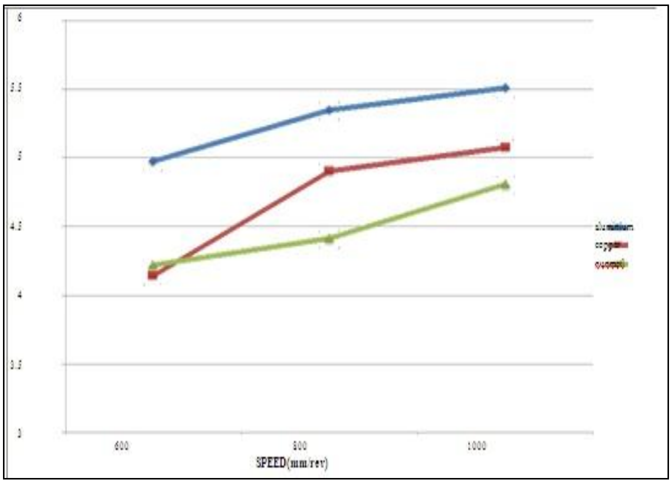


Figure 9: Speed Vs Surface Roughness

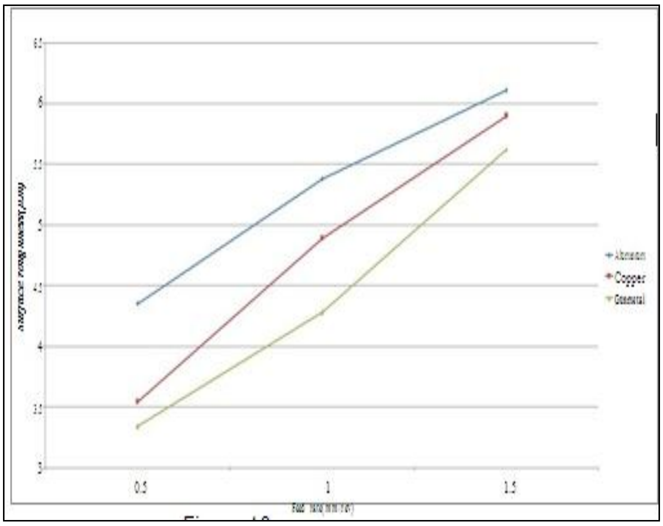


Figure 10: Feed Vs Surface Roughness

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

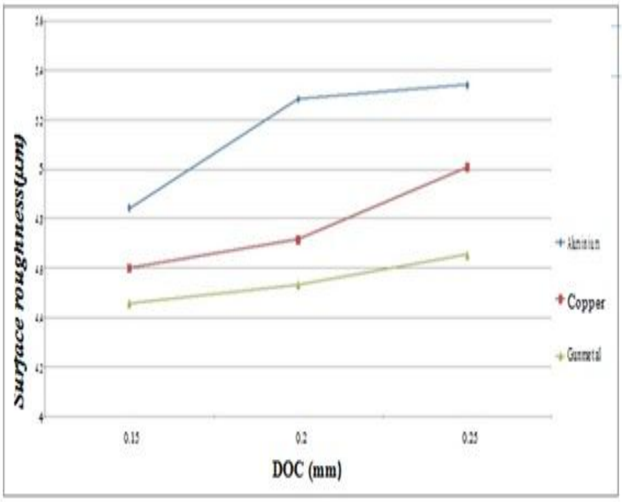


Figure 11: Depth of cut (DOC) Vs Surface Roughness

From the graphs it is evident that, as Speed increases Surface Roughness increases for Aluminum, Copper and Gunmetal. Surface Roughness of Aluminum is more than copper and gunmetal. On X-axis Speed values and on Y-axis Surface Roughness values are taken. Similarly, as Feed rate increases Surface Roughness increases for Aluminum, Copper and Gunmetal. Surface Roughness of Aluminium is more than copper and gunmetal. On X-axis Feed rate and on Y-axis Surface Roughness values are taken. Alongside, as Depth of Cut increases Surface Roughness increases for Aluminium, Copper and Gunmetal. Surface Roughness of Aluminium is more than copper and gunmetal. On X-axis Depth of cut and on Y-axis Surface Roughness values are taken.

IV.CONCLUSION

From the above analysis it is concluded that, to obtain Optimum Material Removal Rate (MRR), and Surface Roughness, cutting parameter should be set as high as possible. By comparing MRR of all the metals taken in experiment aluminum has highest Material Removal Rate followed by copper and gunmetal. From ANOVA analysis, parameters making significant effect on material removal rate is feed rate followed by speed for aluminum, copper and gun metal. As Speed, Feed rate, Depth of cut increases Surface Roughness increases. By observations surface roughness increases with increase in Material Removal Rate.

REFERENCES

[1] Kirankumar, "Optimization of turning process parameters for AISI 1040 steel using Taguchi method", International Journal of Mechanical Engineering and Technology, 2012, 3 (1), 226-234.
[2] Gaurav Kumar., "A Comparative Analysis of Surface roughness and Material removal rate in Milling Operation of AISI 410 steel and Aluminium 6061, Journal of Engineering Research and Applications, "vol.4, issue 6, pp. 89-93, June 2014.
[3] Rajesh Khatri, Dr. P.M. Mishra., "Optimization of material removal rate on Dry turning of AISI 1045 Steel, International Journal of Engineering Research & Technology,"vol.2, issue 1, Jan 2014.
[4] Jayaramana, "Multi-response Optimization of Machining Parameters of Turning AA6063 T6 Aluminium Alloy using Grey Relational Analysis in Taguchi Method", Procedia Engineering, vol. 97, pp 197 – 204, 2014.
[5] Kaladhar, "Application of Taguchi approach and Utility Concept in solving the Multi objective Problem when turning AISI 202 Austenitic Stainless Steel", Journal of Engineering Science and Technology Review, vol. 4, issue 1, pp 55-61, 2011.
[6] Pawar,"Comparative performance analysis of insert geometry by CNC turning of HSS (M2) and Taguchi Method", International Journal of Research in Advent Technology , Special Issue, pp 55-58, 2015
[7] Das, "Optimization of cutting parameters on tool wear, work piece surface temperature and material removal rate during turning of AISI D2 steel, International Journal of Engineering Research & Technology, "vol.1, issue 5, pp. 1-10, 2012.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)